

Technology Challenges for Enabling Future Low-Cost Large Aperture UV Telescopes in Space using a Photon Sieve (PS)

Airapetian, V. S.¹, Carpenter, K. G.², Davila, J.², Upton, R.¹, Daw, A.² & Marzouk, M.¹

Astronomical observations with extremely high spatial resolution have opened new avenues in astrophysics. For example, studies of Active Galactic Nuclei (AGN) obtained with the Hubble Space Telescope provided some of the first clues to properties of accreting supermassive black holes and their effect on their host galaxies. While advances in adaptive optics technology have dramatically increased the resolution of large ground-based telescopes to the level of a few mas (10^{-3} arcsec), space-based observations remain crucial. Coverage can be obtained from space-based observations in the UV and X-ray bands, where most AGN activity occurs, point spread functions remain stable, and objects can be tracked over many hours. Yet, our understanding of the formation and evolution of galaxies is fundamentally limited by a single technological hurdle: the need for ultra high-resolution angular resolution in the UV. Although recent astronomical instruments have demonstrated significant improvements in spatial resolution, field-of-view, and temporal resolution, it is very difficult to manufacture these telescopes to provide spatial resolution at the mas level in the FUV and EUV. All current space telescopes operating in far UV bands yield resolutions significantly larger than the diffraction limit. To approach diffraction limited imaging, primary and secondary mirrors would need to be manufactured with figure errors of order 6 nm, an accuracy not achievable at this time on large concave and convex optics. Diffractive imaging offers the potential of obtaining extremely high-resolution images using elements with relatively relaxed manufacturing tolerances. A photon sieve (PS), a novel version of the Fresnel zone plate (FZP), may provide a viable, low-cost opportunity to reach the diffraction limit in UV and X-ray imaging with lightweight, large apertures. However, a PS has not yet been designed and successfully demonstrated for UV imaging. We propose development of this technology to be pursued in coming

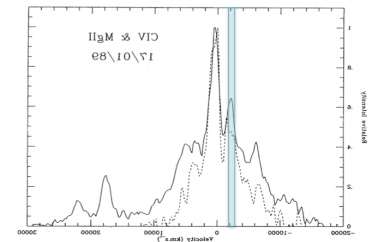


Figure 1: Scanning across velocity-broadened line profiles will allow to measure 2-D velocity fields for AGN and thus measure black hole mass.

decades, as a PS will have four major advantages with respect to conventional imaging technologies: 1. It will be relatively insensitive to variations in surface quality and in hole position introduced by the manufacturing process, so a PS can thus have a larger diameter than conventional optics, with a much smaller mass/diameter ratio. 2. It will be able to overcome conventional constraints for imaging in the UV band set by manufacturing tolerances and assembly errors. 3. It can provide a diffraction limited spatial resolution at a mas-level, by enabling a 5m+ telescope at relatively low cost, within a narrow UV spectral band (~ 1 Å wide), 4. It can image within that narrow band, providing a unique capability to construct images within portions of a spectral line (Fig. 1). Such a 5-meter telescope in space will be capable of providing ultra high-resolution (5 mas) narrow band spectral imaging in UV spectral lines in the 1200-1500 Å regime. This will revolutionize our understanding of a wide range of astrophysical processes by (1) dramatically increasing the number of known black hole masses in the local and distant Universe; (2) observing dynamic processes in extra-solar protoplanetary disks; (3) resolving atmospheric structures in evolved stars; (4) tracing star formation rates and mass outflows in active galaxies.

¹ Sigma Space Corporation, MD; ² NASA/GSFC, MD